TRLs – What do they mean?

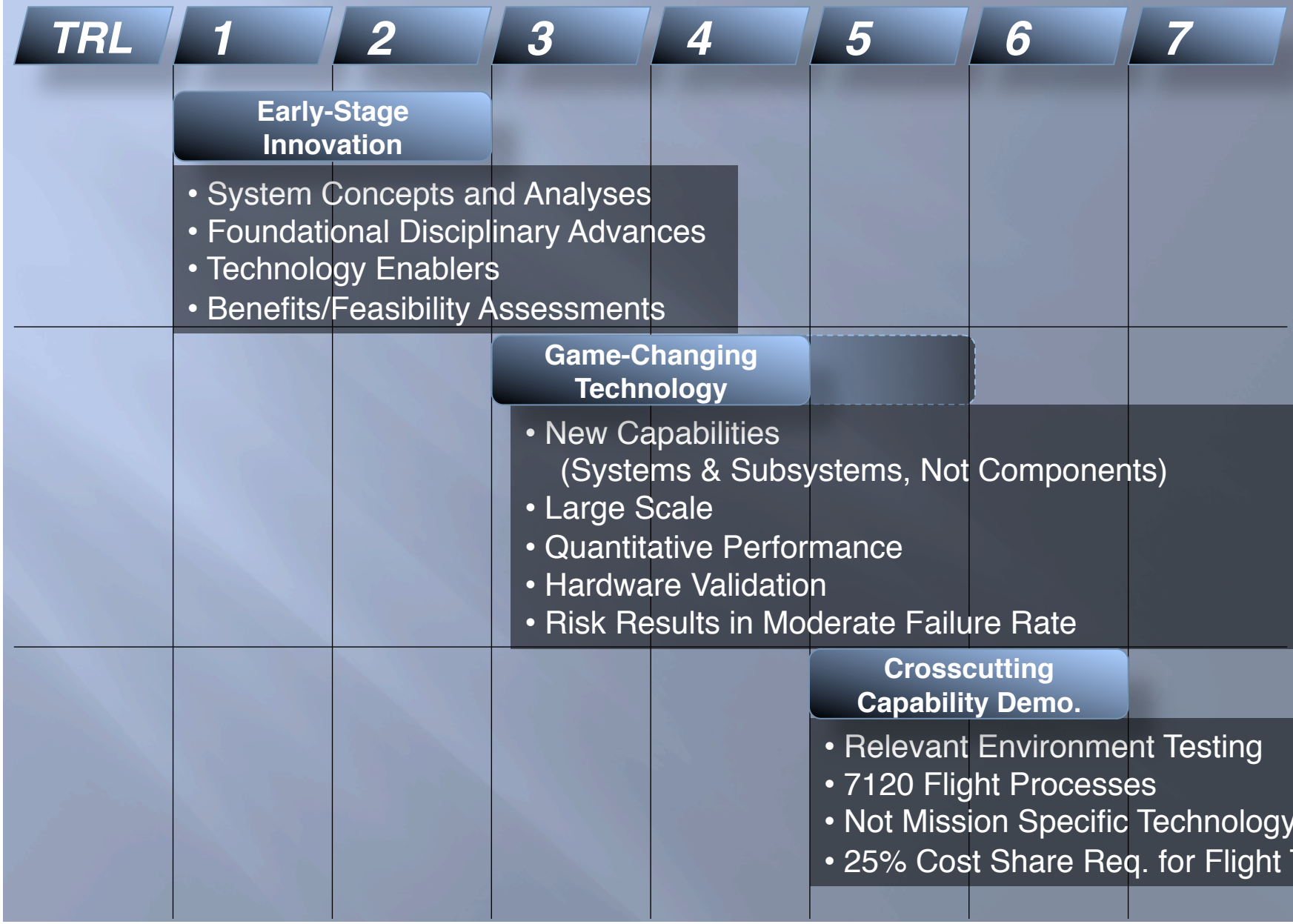
Karen M. McNamara
Office of the Chief Technologist, NASA

TRL: Why are we Talking About It?

- Common "standard" throughout Aerospace
- Criteria for PDR
- Critical to communication with:
  - Partners
  - Suppliers
  - Sponsors
- Effects Project Risk
- Major cause of Project overrun

TRL is a major source of confusion for most Projects

NASA Space Technology Program Elements

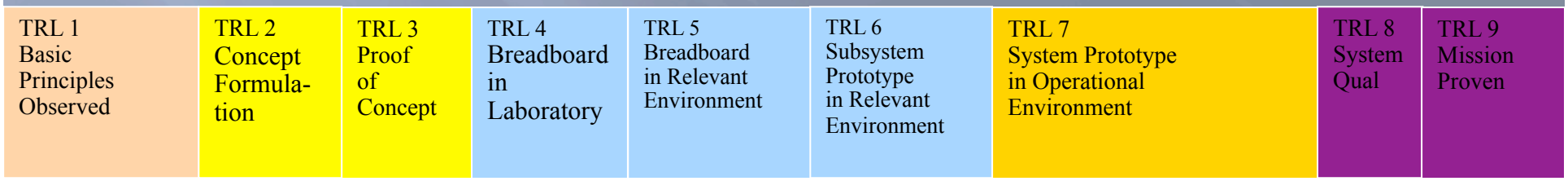


It's not the Definitions: It's the Words

- Breadboard (Brassboard?)
- Prototype (Model?)
- Environment
- Laboratory, Relevant, Operational, (Actual?) Operational
- High, Low, Medium Fidelity
- Validation vs. Demonstration
- "Flight Qualified"

The Easy Ones

- **TRL 1**: Basic principles observed and reported.
  - Scientific knowledge generated underpinning hardware technology concepts/applications.
- **TRL 2**: Technology concept &/or application formulated.
  - Invention begins, practical application is identified but it is speculative, no experimental proof or detailed analysis available to support conjecture.
- **TRL 3**: Analytical & experimental function &/or characteristic proof of concept.
  - Analytical studies place the technology in an appropriate context and laboratory modeling & simulation validate analytical prediction.



TRL 4

- Component &/or Breadboard validation in a laboratory environment.

Low fidelity system/component breadboard is built & operated to demonstrate basic functionality & critical test environments & associated performance predictions are defined relative to the final operating environment.

Description ←

Breadboard = Something has been Built
Laboratory = Not the Real World
Validate < Demonstrate < Verify

TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Basic Principles Observed	Concept Formula-tion	Proof of Concept	Breadboard in Laboratory	Breadboard in Relevant Environment	Subsystem Prototype in Relevant Environment	System Prototype in Operational Environment	System Qual	Mission Proven

TRL5

- Component &/or Brassboard validation in a relevant environment.

The relevant environment is the specific subset of the operational environment that is required to demonstrate critical "at risk" aspects of the final product performance in an operational environment. It is an environment that focuses specifically on "stressing" the technology advance in question.

Description

A medium fidelity system/component brassboard is built and operated to demonstrate overall performance in a simulated operational environment with realistic support elements that demonstrate overall performance in critical areas. Performance predictions are made for subsequent development phases.

TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Basic Principles Observed	Concept Formula-tion	Proof of Concept	Breadboard in Laboratory	Breadboard in Relevant Environment	Subsystem Prototype in Relevant Environment	System Prototype in Operational Environment	System Qual	Mission Proven

TRL 6 = PDR

- System/subsystem model or prototype demonstration in a relevant environment.

Prototype = 3Fs ➔ FORM, FIT, FUNCTION

*Not Necessarily Full Scale

Description

A high fidelity system/component prototype that adequately addresses all scaling issues* is built and operated in a relevant environment to demonstrate operations under critical environmental conditions.

TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Basic Principles Observed	Concept Formula-tion	Proof of Concept	Breadboard in Laboratory	Breadboard in Relevant Environment	Subsystem Prototype in Relevant Environment	System Prototype in Operational Environment	System Qual	Mission Proven

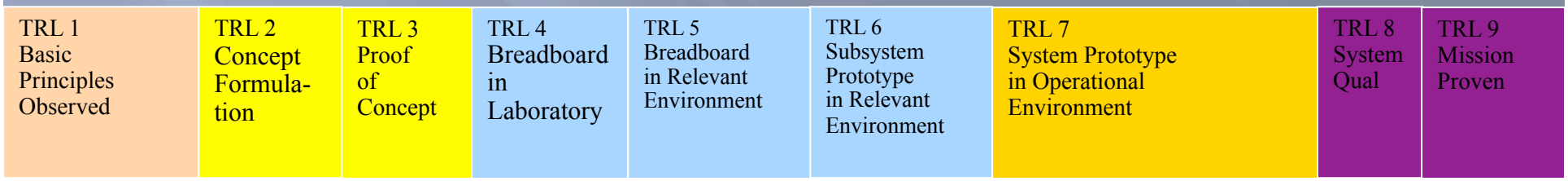
TRL 7

- System prototype demonstration in an operational environment.

The environment in which the final product will be operated. In the case of space flight hardware/software, it is space. In the case of ground-based or airborne systems that are not directed toward space flight, it will be the environments defined by the scope of operations.

Description

A high fidelity engineering unit that adequately addresses all critical scaling issues is built and operated in a relevant environment to demonstrate performance in an actual operational environment and platform (ground, airborne, or space).



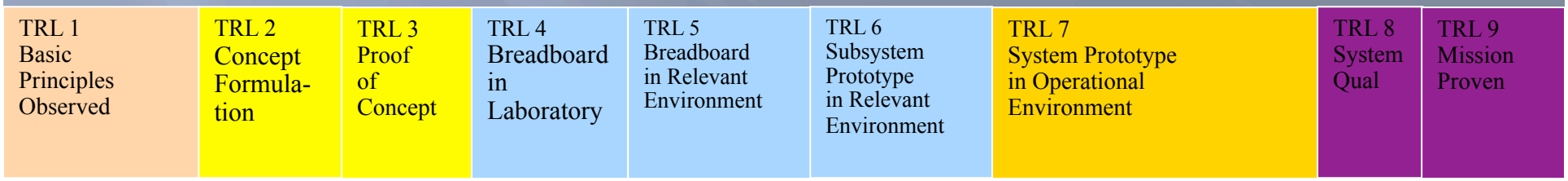
TRL 8

- Actual system completed and "flight qualified" through test and demonstration.

If it's going to fly, the only way to be "flight qualified," is to fly!

Description

The final product in its final configuration is successfully demonstrated through test and analysis in its intended operational environment and platform (ground, airborne, or space).



TRL 9

- Actual system flight proven through successful mission operations.

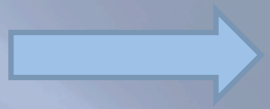
The final product is successfully operated in an actual mission.

TRL 1 Basic Principles Observed	TRL 2 Concept Formula-tion	TRL 3 Proof of Concept	TRL 4 Breadboard in Laboratory	TRL 5 Breadboard in Relevant Environment	TRL 6 Subsystem Prototype in Relevant Environment	TRL 7 System Prototype in Operational Environment	TRL 8 System Qual	TRL 9 Mission Proven

FUN FACTS ABOUT TRLs

ALL TRLs ARE NOT CREATED EQUAL

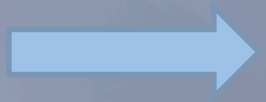
System/subsystem model or prototype demonstration in a relevant environment TRL6



System prototype demonstration in an operational environment TRL7

Is much harder than

Component and/or breadboard validation in relevant environment TRL5



System/subsystem model or prototype demonstration in a relevant environment TRL6

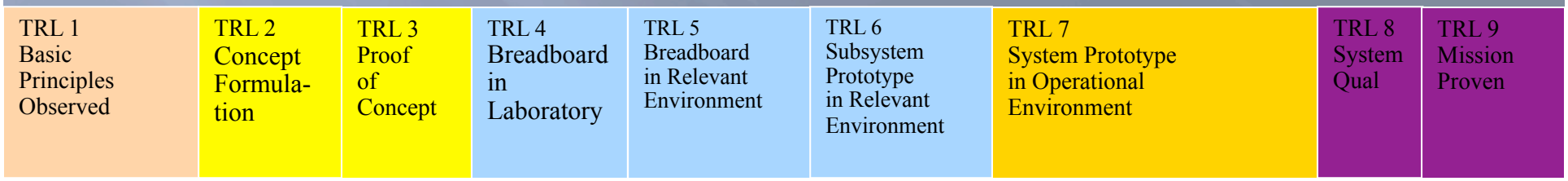
TRL 1 Basic Principles Observed	TRL 2 Concept Formula-tion	TRL 3 Proof of Concept	TRL 4 Breadboard in Laboratory	TRL 5 Breadboard in Relevant Environment	TRL 6 Subsystem Prototype in Relevant Environment	TRL 7 System Prototype in Operational Environment	TRL 8 System Qual	TRL 9 Mission Proven

FUN FACTS ABOUT TRLs

ALL TRLs ARE NOT CREATED EQUAL

The TRL scale is not linear – or even proportionate:

IN COST
IN SCHEDULE
IN EFFORT



FUN FACTS ABOUT TRLs

What is the TRL of a Planetary Probe?

(THAT HAS NOT YET FLOWN)

The TRL of the entire system is ≤ the TRL of the lowest TRL Component.

FUN FACTS ABOUT TRLs

TRLs CAN CHANGE

A TRL applies:

To the specific component
In the tested environment
For the intended use
In the same configuration

Heritage rarely happens!

FUN FACTS ABOUT TRLs

There is no "standard" within the United States or internationally for TRLs.

The International Standards Organization (ISO) is attempting to coordinate space agencies and other stakeholders to develop and international TRL Standard.

THE BIGGEST ISSUE: TRL 5, 6, 7

Why Does the ISO Effort Matter?

International partnerships

Integration across agencies & industry

Communication with contractors & suppliers

Uncertainty in TRL means increased risk

To Cost
To Schedule
To Mission

What Else?

Exit Criteria

TRL Assessment